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HEATED ELECTRON BEAM CELL STUDY.(U)

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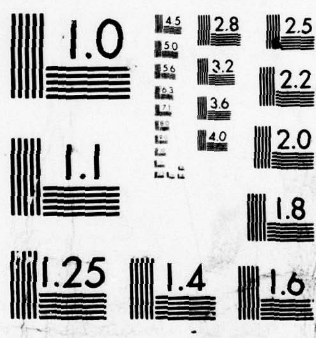

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Heated Electron Beam Cell Study

J. G. EDEN AND S. K. SEARLES

Laser Physics Branch
Optical Sciences Division

March 12, 1979

NAVAL RESEARCH LABORATORY
Washington, D.C.

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The design and operation of a new valve and a new cell for high temperature, high pressure operation is reported.

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INTRODUCTION

In general, high power gas lasers operate with simple laser species at room temperature. High power electronic state gas lasers, however, operate only with diatomic rare gas or rare gas halide laser molecules. To increase the number of laser molecules for high power laser operation, it is necessary to raise cell temperatures above room temperature. The alkali metals, Group I, become volatile, at 400-500°C. At even higher temperatures the metals in Groups IIB, IIIA, IVA, and VA have significant vapor pressures. The purpose of this work is to advance the state of the art of high temperature cell design to allow laser discovery experiments to proceed with fewer technical difficulties.

(cont on p i)

HEATED ELECTRON BEAM CELL STUDY
FINAL REPORT
Project #ES-77-A-01-6021

1.0 Components

1.1 Valves. One of the important components of the cell is the valve. One valve is needed to isolate the heated cell so that metal vapor in the cell will not condense out in the tube connecting the cell to the gas handling plant. This problem can be best overcome if the valve is incorporated into the cell itself. The design shown in Fig. 1 places the valve in the cell wall where temperature uniformity can be assured. Temperature uniformity is essential to avoid gas turbulence in the cell. Also, it is often necessary to accurately know the cell temperature to calculate the vapor pressure of the metal vapor in the cell. As an example, if a cell were filled with Cd vapor at a cell wall temperature of 759^{o}K, the calculated equilibrium vapor pressure would be 10 torr. However, if the valve temperature were only 4^{o}K cooler, the actual pressure would be only 9 torr.

To avoid these experimental problems, a new valve is shown schematically in Fig. 1. The seal is made by a ball bearing forced against a seat by a spring. The valve is opened either by filling the cell with high pressure gas used for laser experiments or by retracting the ball by turning in the threaded metal rod. Once the cell is filled with gas, the metal rod can be retracted to eliminate a heat sink to the cell. A

Note: Manuscript submitted January 10, 1979.

valve was built and tested to determine the valve leak-through rate. This valve had the following characteristics. The ball was a 5/16" diameter standard steel ball bearing held by a spring manufactured from .085" diameter wire at 8 turns per inch over its 1.8" length. In the valve closed position, the spring was compressed by 20%. The ball seated itself against a 1/4" diameter hole drilled in a stainless steel plate. The valve could be opened by a threaded 1/8" diameter rod whose end was cupped to fit the curvature of the ball bearing. The valve was tested at room temperature with one side open to atmospheric pressure and the other side pumped by a small mechanical vacuum pump. The valve leak-through rate was small enough that a vacuum of 20 mtorr was obtained. This rate is small enough that the valve could be used as part of a high temperature, high pressure cell.

1.2 Windows. Another important component of the cell is the window used to extract optical radiation from the cell. There are several choices for the window. One choice is a commercially available sapphire window brazed to a metal sleeve. Sapphire has the advantage of strength and good thermal conductivity but the disadvantages of high reflective losses due to a high index of refraction. Commercial window assemblies can be either welded or silver soldered to the high temperature cell. Both welding and silver soldering require inert gas blankets over the pieces during the joining process. Silver soldering can be done in the lab by directing a flow of inert gas over the window face. The gas flow also serves to keep the window cool during the soldering process.

In practice, some mounted commercial sapphire assemblies were successfully used at temperatures up to 700°C and pressures up to 2 atmospheres of metal vapor and rare gas. Other mounted commercial assemblies developed leaks in the vicinity of the sapphire window to sleeve braze. It is believed that certain brazes fail due to amalgamation with the metal vapor. The metal vapors which caused failure are mercury, potassium, and sodium.

Fused silica windows sealed onto Mo sleeves are an alternative to the sapphire window assemblies. A 1.9 cm diameter fused silica-Mo assembly was tested for survival under extreme conditions. At 600°C the window withstood a load of 10 atm of inert gas for 30 minutes. When the pressure was increased to 19 atm the window shattered.

1.3 Cell Material. Finally, a quick survey of metal alloys for the cell body was made. One would like high thermal conductivity to reduce temperature non-uniformities, high strength to reduce warping caused by compressing a metal gasket, the appropriate thermal expansion coefficient to prevent leaks during temperature cycling and resistance to corrosion or amalgamation by the laser gases. Monel 400 is attractive because of its conductivity and resistance to corrosion. Inconel 600 is attractive because of its strength and resistance to corrosion at high temperatures. In addition, screws to bolt the cell together are available in both Monel and Inconel. Mismatching the screw and cell materials can make the thermal cycling problem much more difficult.

2.0 Cell Construction

As part of a continuing research program to assess the potential of various metal excimers as laser fusion amplifiers, considerable effort has been devoted to developing electron beam laser cells that will satisfy stringent mechanical and chemical corrosion requirements. As stated in our proposal for this project, the characteristics of a cell suitable for laser experiments are that it:

a) be free of medium turbulence and window fogging (i.e., temperature uniformity),

b) should withstand temperature cycling, and

c) be capable of continuous and prolonged operation at 500-600^{o}C.

A cell that meets the above requirements has been designed, constructed and tested and is shown schematically in Fig. 2. The cell consists simply of an approximately 4 cm diameter stainless steel tube (with 2 3/4" o.d. Varian fittings on each end) welded to an approximate 1 cm thick stainless steel plate. Also, the cell is constructed entirely of stainless steel to minimize undesirable gaseous impurities. The windows are re-entrant and can be sapphire or quartz. Either sapphire-to-stainless steel or quartz-to-molybdenum seals are available commercially which were then heliarc-welded into a Varian 2 3/4" o.d. blankoff fitting. A vacuum tight (better than 10^{-6} torr) seal between the fitting and the laser cell body was then made using either copper, nickel or stainless steel gaskets. Although it is not shown in the figure, provision was also made to evacuate the region on the outside of each window to prevent condensation of metal on the inner surface.

A great deal of time was spent in perfecting the welding of foils to the laser cell body. On the advice of Drs. Chou and Zawadzkas of Exxon, an engraving tool from H. T. Preis and Co. in New Jersey was purchased. However, even with this tool, great care must be exercised in order to obtain welds that are leak tight and will withstand large pressures in the cell. The steps that must be taken in the welding process are:

a) Before welding, water should be squirted over the welding surface.

b) The foil should be positioned and clamped between the laser cell and a 2-4" thick plastic block. The block prevents the foil from buckling during welding.

c) During welding, water should be continuously squirted in front of the welding tip to keep the foil cool.

d) A secure weld is made by "tacking" the foil down by making a rectangular weld. Successive welds are also rectangular and lie inside this first weld.

Using these steps, it was found possible to weld virtually any type of foil (Inconel, stainless steel, titanium, Monel, etc.) to the laser cell. Also, the welds were tested up to 75 psi pressure and will almost certainly withstand much more.

One of the chief advantages of using the welded foil rather than metal gaskets is that the welds will withstand repeated temperature cycling. In contrast, the gold or aluminum gaskets used previously lost the vacuum seal once the cell was cooled. Gasket seals <u>will</u> hold with temperature cycling if the gasket is crushed over a knife edge. This

was the case with seals holding on the cell windows and no problems were encountered. However, simply compressing the gasket between two flat surfaces is sufficient to hold a vacuum at high temperature but the system will not temperature cycle.

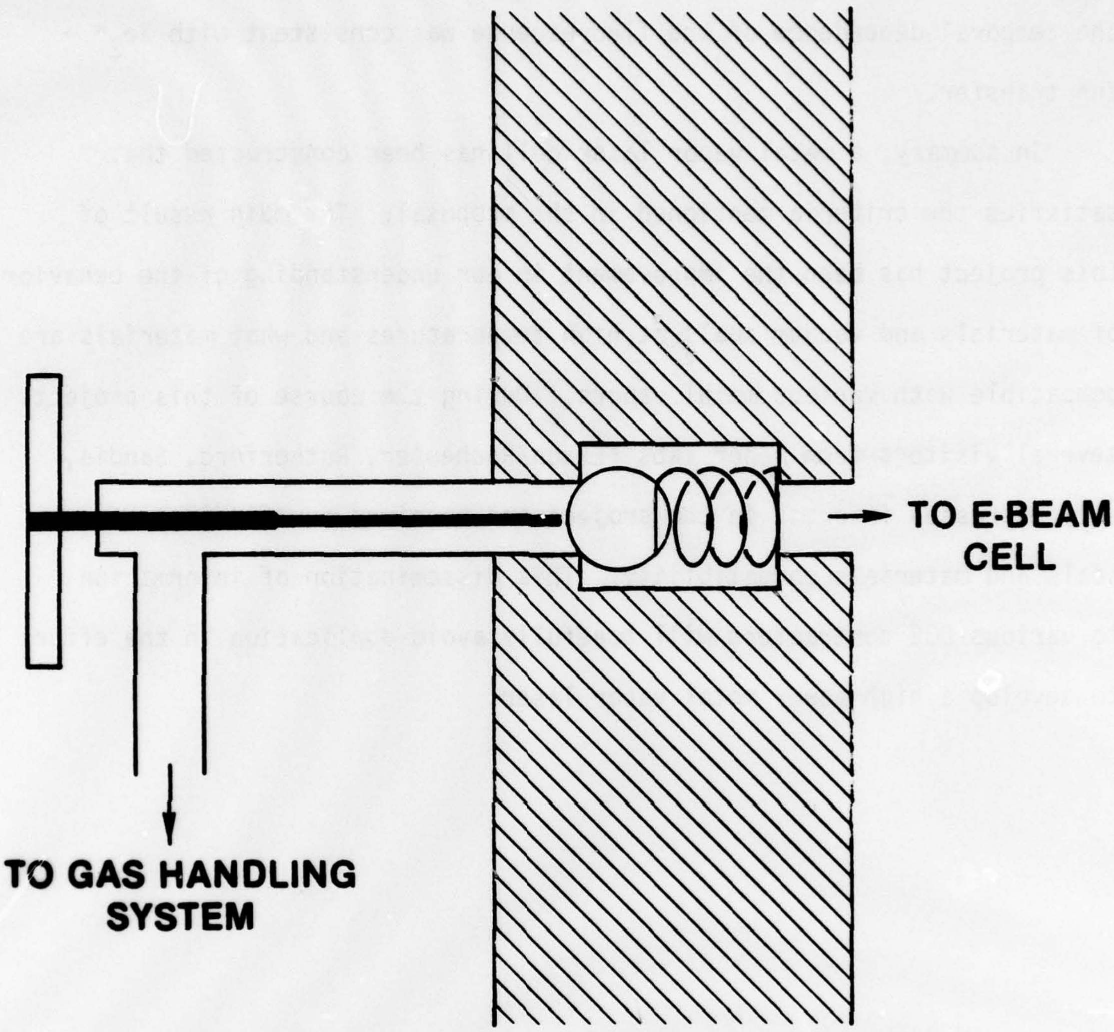
To introduce the desired metal into the system, either a sidearm (with separate temperature control) was used or a quartz boat containing metal pellets was inserted in the cell. Temperature along the length of the cell was monitored by several alumel-chromel thermocouples. Even at the highest temperatures studied, the temperature uniformity of the cell was found to be $10^{o}C$. This could likely be improved by adding perhaps one more heater to allow direct heating of the window flanges. The transite plate at the rear of the oven enclosure had a strong effect on both the oven's temperature uniformity and the maximum operating temperature. With this design, the major heat loss from the loss is radiation into the e-gun diode.

After completion of the cell, several runs were made with zinc vapor to study the cell's suitability for laser experiments. The cell was operated to $T \sim 750^{o}C$ ($P_{Zn} \sim 122$ Torr) and window fogging was never observed. Convection currents inside the cell were found to be negligible.

Figure 2 shows partial energy level diagrams for Zn and Xe. The close energy coincidence between low lying electronic states of Xe_2 and the Zn 5^3S state illustrates the possibility of efficient $Xe_2^* \rightarrow Zn^*$ energy transfer followed by radiation to the 4^3P levels. Such a mechanism could selectivity populate the Zn (4^3P) states in a Xe/Hg/Zn vapor mixture containing small concentrations of Zn and Hg (see Fig. 2).

Experiments were performed for xenon pressures up to 4000 Torr and cell temperatures up to 750°C. Strong $5^3S \rightarrow 4^3P$ emission was observed and the temporal dependence of the fluorescence was consistent with $Xe_2^* \rightarrow Zn^*$ transfer.

In summary, a metal vapor laser cell has been constructed that satisfies the criteria mentioned in the proposal. The main result of this project has been the improvement in our understanding of the behavior of materials and vacuum seals at high temperatures and what materials are compatible with various metal vapors. During the course of this project, several visitors from major labs (Exxon/Rochester, Rutherford, Sandia, LLL) expressed interest in the project and received our findings on seals and materials compatibility. This dissemination of information to various DOE contractors will hopefully avoid duplication in the effort to develop a high power metal vapor laser.



**NRL VALVE
CONCEPTUAL DRAWING**

Fig. 1 — High temperature valve

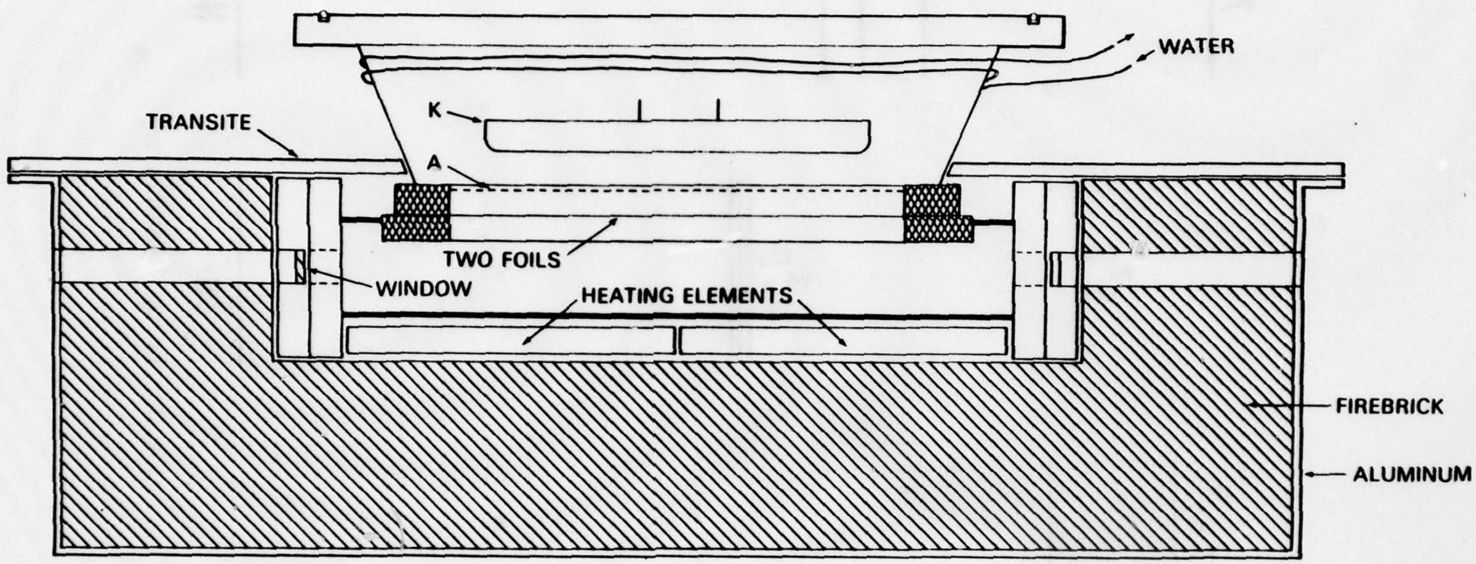


Fig. 2 — Schematic diagram of the metal vapor cell and oven

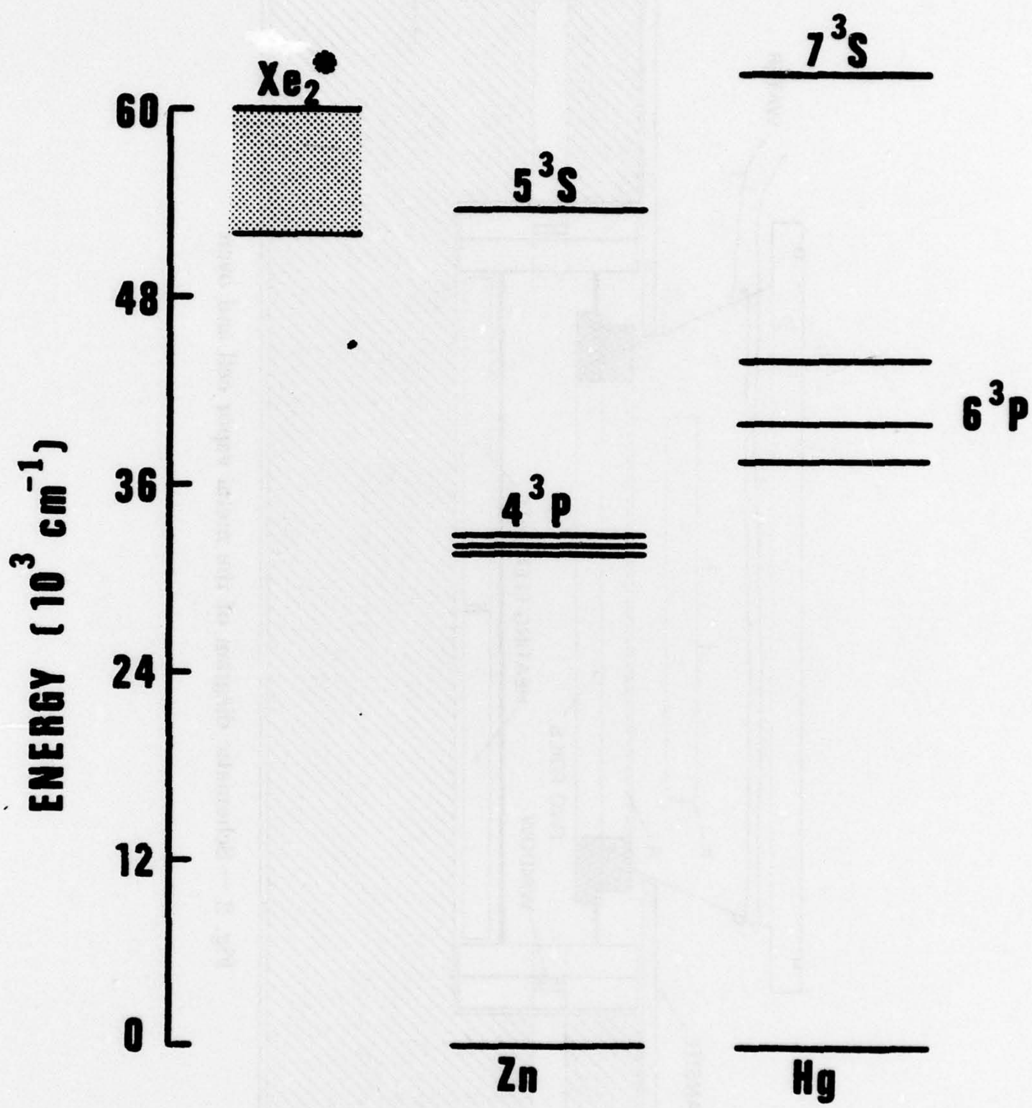


Fig. 3 — Energy level diagram